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ENERGY SECURITY: ESTABLISHING A LOW CARBON ENERGY MIX AND ROADMAPS TO CARBON NEUTRALITY IN ELECTRICITY CONSUMPTION FOR AIRPORTS IN SOUTH AFRICA

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ABSTRACT

Establishing a low carbon energy mix for developing countries is a multidimensional challenge and most organisations that embark on such a challenge are not successful and find themselves either reverting to paying for energy that is not guaranteed, or relying on a developing market of private energy service providers usually in the renewable energy sector involving South Africa's wind and solar energy independent power producers. The challenges associated with establishing power generation that is quite different from the established power generation energy sources stems from unfamiliar power generation technologies, technology markets, skills for operations and maintenance. These challenges have the common ground of increased relative cost and business risk. This paper presents the process for the establishment of energy generation technologies forming a low carbon energy mix that is economically feasible and technically suited to the operating environment to ensure a reliable and feasible transition for nine airports in South Africa to realise energy security.

KEYWORDS: Techno-Economic Assessments, Renewable energy, Alternative Energy, Feasibility of Renewable Energy, Geothermal Heat Sinks, Solar PV Energy, Energy Reduction Projects, Low Carbon Energy Mix, Solar Thermal Absorption Cooling, Solar Thermal Deflection Innovation, Air Conditioning Energy Reduction, LED Lighting Technology, Lighting Control, Natural Gas Trigeneration, Energy Security, Carbon Neutrality & Green Buildings

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Original Article

1. INTRODUCTION

Airports Company South Africa (ACSA) owns and operates nine airports in South Africa, namely, O R Tambo International Airport (ORTIA) (Kempton Park, Gauteng), Cape Town International Airport (CTIA) (Western Cape), King Shaka International Airport (KSIA) (Durban, KwaZulu-Natal), Port Elizabeth International Airport (Eastern Cape) (PEIA), East London Airport (Eastern Cape) (EL), Bram Fischer International Airport (Bloemfontein, Free State) (BFIA), George Airport (Eastern Cape) (GG), Upington International Airport (Northern Cape) (UPIA) and Kimberley Airport (Northern Cape) (KIM).

ACSA's objective is to establish an energy mix that is feasible and suitable for the operating environment in their strategic journey to reach carbon neutrality in electricity consumption which is the largest constituent of the airports' carbon footprint. Reducing the airports' electricity consumption is an objective in the journey towards carbon neutrality together with the establishment of certified green star rating of existing terminal buildings and certifying all new office, terminal and commercial buildings with green star ratings to ensure that the investment into energy efficiency, energy conservation and alternative energy mix is sustained, and investments preserved. Green star rating of terminal buildings is included as a goal regardless of the financial viability of this process as the

operational and efficiency benefits far outweigh the direct financial benefit.

This paper presents the confirmed energy mix for all nine airports, including the feasible alternative energy projects, their energy reduction projects, and the green star rating targeted for all airports.

2. FINALISING THE LOW CARBON ENERGY MIX AND ROADMAPS TO CARBON NEUTRALITY IN ELECTRICITY CONSUMPTION FOR NINE AIRPORTS

Determining a feasible energy mix for airports starts with the preliminary work of ascertaining and analysing the airports' energy consumption followed by reducing the airports' electricity demand [1] [2] [3]. This involves assessment of the energy demand profiles and determination of the alternative low carbon energy sources available to each site, then conducting technoeconomic assessments regarding the adoption of the alternative energy sources identified to supply the energy demand [4] [5] [6] [7]. Following the principles for energy efficiency [8] and the principles for energy security [9], the energy source identified can be matched to the energy demand considering the shortest energy conversion route, considering the site specific constraints, and optimising for cost effectiveness (Figure. 1).

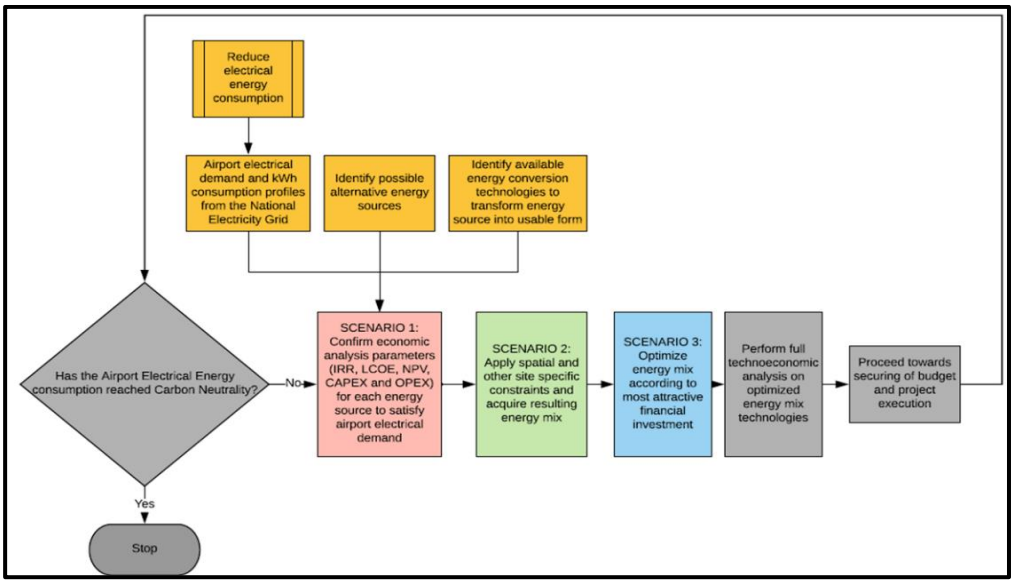

Figure 1: Flowchart: Energy Mix Determination Towards Carbon Neutrality in Electricity Consumption at Airports.

Based on the conceptualised low carbon energy mix per airport [10], and the technoeconomic assessments, the final low carbon energy mix reaching carbon neutrality is shown in Figure. 2 to Figure. 10, each figure is followed by a table with the project details, Table 1 to Table 9. The roadmaps to carbon neutrality use the energy consumption of the airports during the period 1 April 2019 to 31 March 2020 or 2019/20 financial year (FY 2019/2020) as a baseline to offset carbon emissions, with the first reduction noticeable in the FY 2021/2022 (1 April 2021 to 31 March 2022).

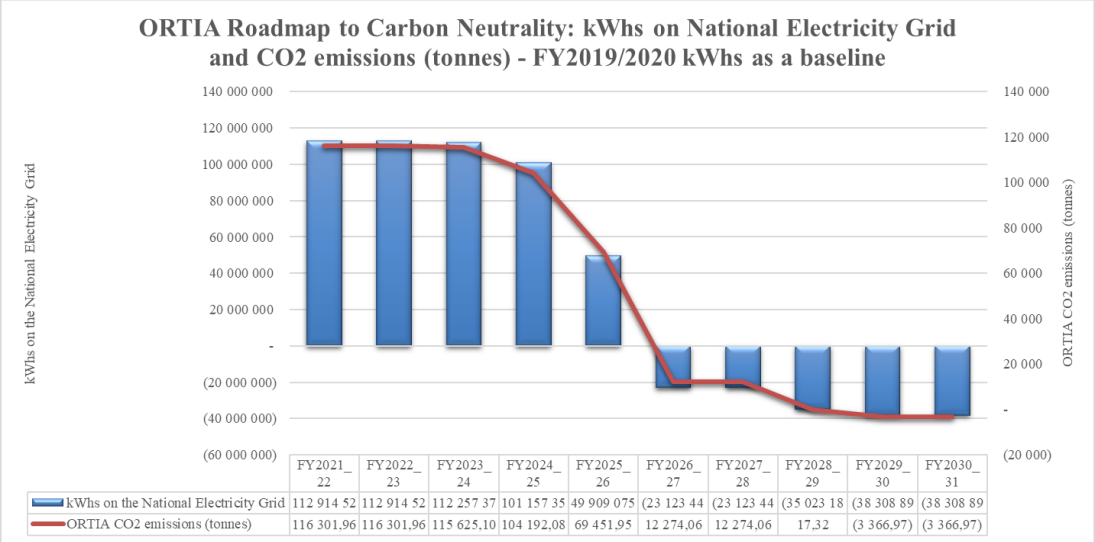

Figure 2: ORTIA Roadmap to Carbon Neutrality in Electricity Consumption.

ORTIA's roadmap to carbon neutrality (Figure. 2 and Table 1) shows a reduction of electricity consumption from the grid, a reliance on natural gas trigeneration as a main power source, and an excess generation of kWhs as a result of using a carbon offsetting technique for generating green kWhs via a solar PV plant so that carbon credits can be claimed to offset carbon emissions and excess kWhs can be sold commercially.

Table 1: ORTIA Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	ORTIA Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% impact on kwh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED	1.1	Runway	2026	5 914 278.24		11.52 %	14.99 %
		1.2	Cargo warehouse	2023	657 142.03			
		1.3	Streetlighting	2025	1 642 855.07			
		1.4	High-masts	2024	985 713.04			
		1.5	Phase 1 replacement	2024	4 928 565.20			
		1.6	Phase 2 replacement	2029	3 285 710.13			
	Lighting control	2.1	Lighting control system	2025	11 609 509.14		7.68 %	9.99 %
	Heat deflective coating	3.1	Application on terminal building roof	2028	7 255 943.21		4.80 %	6.25 %
	Geyser sleeve	4.1	Geyser sleeve	2026	98 550.00		0.07 %	0.08 %

	technology		retrofit					
	HVAC energy savings	5.1	Active chilled water setpoint control	2024	2 229 828.00		1.47 %	1.92 %
Energy mix	Natural gas	6.1	10.5 MWp (electrical) natural gas trigeneration	2025 (50 %); 2026 (100 %)	29 023 772.85 (HVAC energy consumption)	70 080 000.00	65.53 %	55.14 %
	Carbon offsetting plant	7.1	Solar PV plant 5.3 MWp	2024 (33 %); 2025 (66 %); 2026 (100 %)		8 867 748.00	5.86 %	7.63 %
	Smart grid	8	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency culture	Existing terminal buildings green star rating	9.1	5-star green rated terminal	2028	4 643 803.66		3.07 %	4.00 %
		10	Maintain terminal building green star rating					
Total kWhs off the national electricity grid						**151 223 418.57**	**100 %**	
Total CO_2 emissions offset (tonnes)						**119 668.92**		**100 %**

CTIA's roadmap to carbon neutrality (Fig. 3, Table 2) shows a reduction of electricity consumption from the grid, a reliance on natural gas trigeneration as a main power source, incorporation of a geothermal heat sink to replace a cooling tower, vertical axis wind turbines, and excess generation of kWhs as a result of using a carbon offsetting technique for generating green kWhs through a solar PV plant so that carbon credits can be claimed to offset carbon emissions and kWhs can be sold commercially.

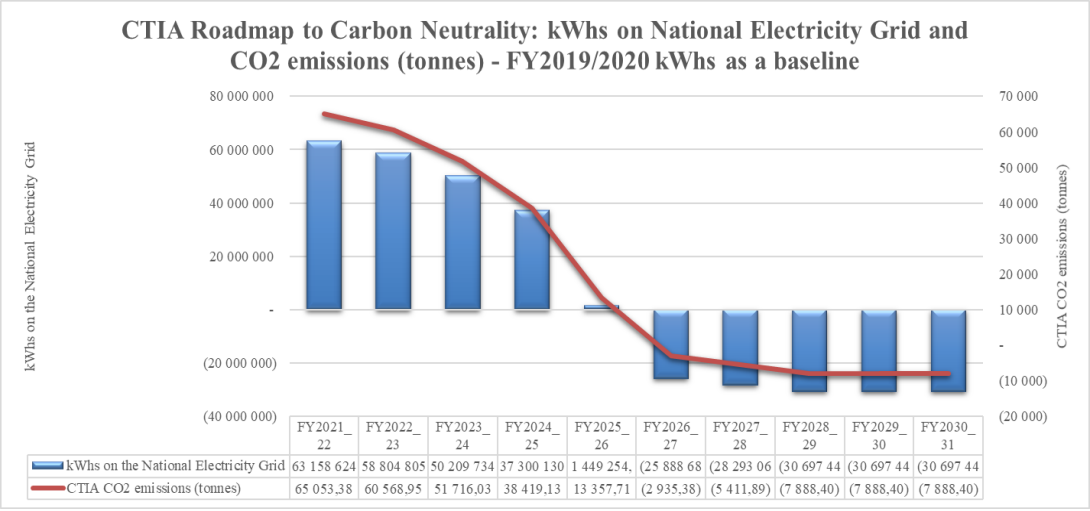

Figure 3: CTIA Roadmap to Carbon Neutrality in Electricity Consumption.

Table 2: CTIA Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	CTIA Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED	1.1	Parking areas	2026	240 437.92		15.74 %	20.86 %
		1.2	Terminal	2023	1 815 306.31			
		1.3	High-masts	2025	577 051.01			
		1.4	Runway	2024	120 218.96			
		1.5	Mass LED retrofit (4 years)	2025; 2026; 2027; 2028	9 617 516.88			
		1.6	LED retrofit and control	2024	2 404 379.22			
	Lighting control	2.1	Lighting control system	2023	2 404 379.22		2.56 %	3.40 %
	Heat deflective coating	3.1	Application on terminal building roof	2024	4 294 822.38		4.58 %	6.06 %
	Geyser sleeve technology	4.1	Geyser sleeve retrofit	2024	19 710.00		0.02 %	0.03 %
	HVAC energy savings	5.1	Chilled water setpoint and fresh air demand control	2024	1 486 552.00		1.58 %	2.10 %
Energy mix	Natural gas	6.1	7 MWp (electrical) natural gas trigeneration	2025 (50 %); 2026 (100%)	1 894 758.75	46 077 600.00	51.11 %	35.21 %
	Geothermal heat sink	7.1	Cooling Towers at Terminal 1	2022	114 253.40		0.12 %	0.16 %
	Carbon offsetting plant	8.1	Solar PV plant 11 MWp	2023 (33 %); 2024 (66 %); 2025 (100 %)		18 572 076.00	19.79 %	26.23 %
	Vertical Axis Wind Turbines	9.1	255 kWp wind plant	2025		781 146.50	0.83 %	1.10 %
	Smart grid	10	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency	Existing terminal buildings	11.1	6-star green rated terminal	2025	3 435 857.91		3.66 %	4.85 %

culture	green star rating	12	Maintain terminal building green star rating			
Total kWhs off the national electricity grid				**93 856 066.44**	**100 %**	
Total CO_2 emissions offset (tonnes)				**72 941.78**		**100 %**

KSIA's roadmap to carbon neutrality (Figure. 4 and Table 3) shows a reduction of electricity consumption from the grid, a reliance on natural gas trigeneration as a main power source, and excess generation in kWhs as a result of using a carbon offsetting technique for generating green kWhs via a solar PV plant so that carbon credits can be claimed to offset carbon emissions and kWhs can be sold commercially.

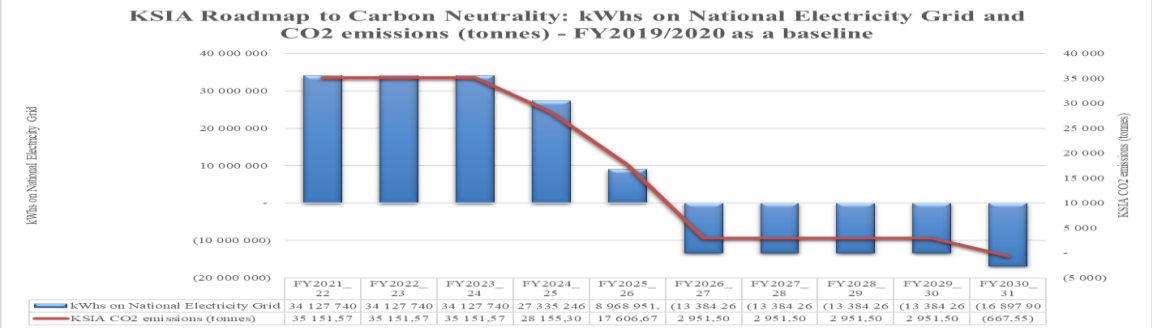

Figure 4: KSIA Roadmap to Carbon Neutrality in Electricity Consumption.

Table 3: KSIA roadmap to carbon neutrality in electricity consumption

Objective	Project Guidance	#	KSIA Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED	1.1	Lighting change to LED	2024	6 772 784.00		13.27 %	19.48 %
	Lighting control	2.1	Lighting control system	2026	3 386 392.08		6.64 %	9.74 %
	Heat deflective coating	3.1	Application on terminal building roof	2025	2 116 495.00		4.15 %	6.09 %
	Geyser sleeve technology	4.1	Geyser sleeve retrofit	2024	19 710.00		0.04 %	0.06 %
Energy mix	Natural gas	5.1	5.25 MWp (electrical) natural gas trigeneration	2025 (50 %); 2026 (100%)	1 023 832.22	32 499 600.00	65.70 %	49.67 %
	Carbon offsetting plant	6.1	Solar PV plant 2.1 MWp	2030		3 513 636.00	6.89 %	10.10 %

	Smart grid	7	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency culture	Existing terminal buildings green star rating	8.1	6-star green rated terminal	2026	1 693 196.04		3.32 %	4.87 %
		9	Maintain terminal building green star rating					
Total kWhs off the national electricity grid						**51 025 645.34**	**100 %**	
Total CO_2 emissions offset (tonnes)						**35 819.12**		**100 %**

PEIA's roadmap to carbon neutrality (Figure. 5, Table 4) shows a reduction of electricity consumption from the grid, a reliance on the existing 1 MWp solar PV powerplant as a main power source, vertical axis wind turbines, incorporation of solar thermal energy for powering absorption chillers, and excess generation in kWhs as a result of extending the existing solar PV plant to cover the airport's remaining electricity demand. There are a few surplus kWhs which can either be sold off commercially or the carbon credits used by another airport. Geyser sleeve technology, although feasible for PEIA [1], was excluded due to the geysers being replaced with heat pumps.

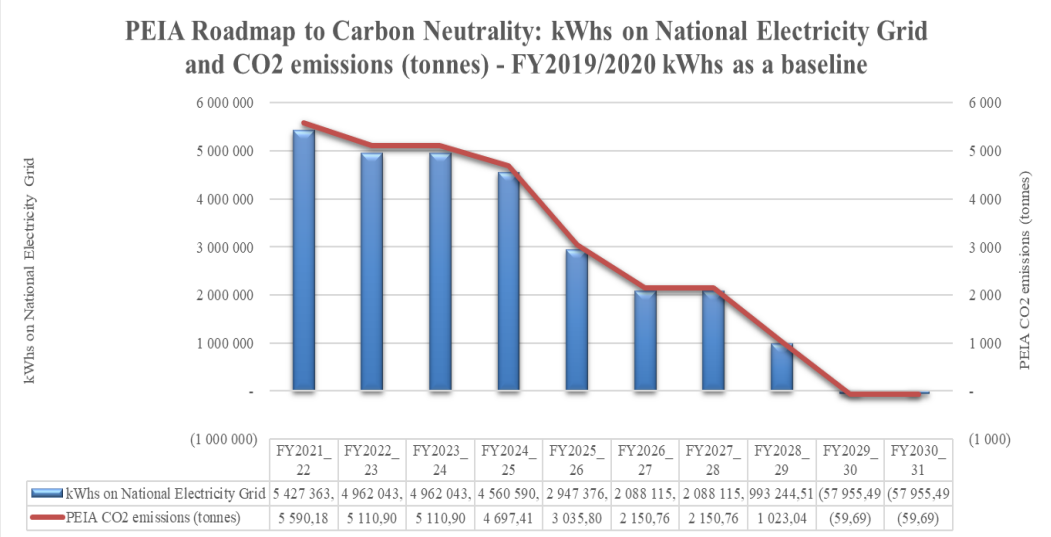

Figure 5: PEIA Roadmap to Carbon Neutrality in Electricity Consumption.

Table 4: PEIA Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	PEIA Project	Date of Beneficial Operation	kWh savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED and lighting control	1.1	Terminal	2024	97 321.90		33.93 %	33.93 %
		1.2	Runway phase 1	2028	425 783.29			
		1.3	Runway phase 2	2028	669 088.03			
		1.4	Mass retrofit	2024	304 130.92			

		1.5	Streetlighting	2025	364 957.11			
	Heat deflective coating	2.1	Application on terminal building roof	2022	465 320.31		8.48 %	8.48 %
Energy mix	Solar thermal absorption cooling	3.1	200 kWp Solar thermal absorption plant	2025	876 000.00		15.97 %	15.97 %
	Vertical axis wind turbines	4.1	280 kWp wind plant	2026		859 261.15	15.66 %	15.66 %
	Solar PV plant expansion required	5.1	600 kWp plant with energy storage for night demand from existing plant and expansion	2029		1 051 200.00	19.16 %	19.16 %
	Smart grid	6	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency culture	Existing terminal buildings green star rating	7.1	6-star green rated terminal	2025	372 256.28		6.79 %	6.79 %
		8	Maintain terminal building green star rating					
Total kWhs off the national electricity grid						**5 485 318.99**	**100 %**	
Total CO_2 emissions offset (tonnes)						**5 649.88**		**100 %**

EL airport's roadmap to carbon neutrality (Fig. 6, Table 5) shows a reduction of electricity consumption from the grid, a reliance on the planned 650 kWp solar PV powerplant as a main power source, and excess generation in kWhs as a result of extending the existing solar PV plant to cover the airport's remaining electricity demand. There are a few surplus kWhs which can either be sold off commercially or the carbon credits used by another airport. Due to the site planning inclusion of heat pumps, geyser sleeve technology was excluded.

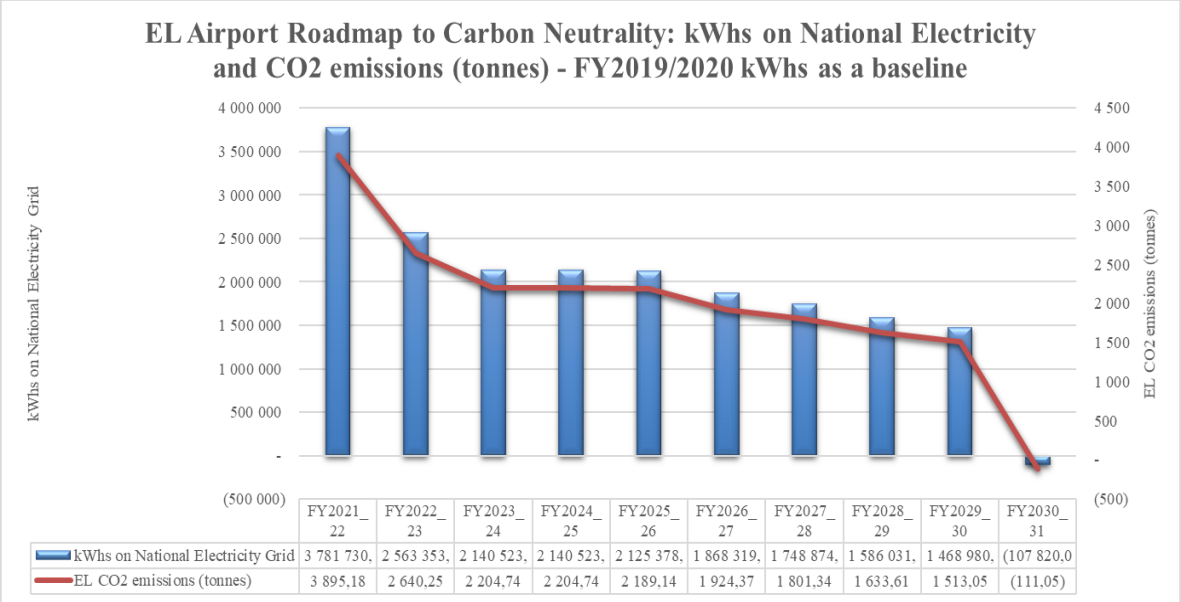

Figure 6: EL Airport Roadmap to Carbon Neutrality in Electricity Consumption.

Table 5: EL Airport Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	EL airport Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED and lighting control	1.1	Staff parking	2025	15 144.87		25.46 %	25.46 %
		1.2	Terminal and parking areas	2027	119 445.07			
		1.3	Runway phase 1	2028	162 843.06			
		1.4	Runway phase 2	2026	87 926.93			
		1.5	Runway phase 3	2029	117 051.24			
		1.6	Runway phase 4	2022	64 848.33			
	Lighting control	2.1	Lighting control system	2023	422 830.00			
	Geyser sleeve technology	3.1	Heat pumps (instead)	2022	14 728.50		0.38 %	0.38 %
Energy mix	Planned solar PV plant	4.1	Solar PV plant 650 kWp	2022		1 138 800.00	29.28 %	29.28 %
	Solar PV plant expansion required	5.1	900 kWp plant with energy storage for night demand	2030		1 576 800.00	40.54 %	40.54 %

			from existing plant and expansion					
	Smart grid	6	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency culture	Existing terminal buildings green star rating	7	5-star green rated terminal	2026	169 132.00		4.35 %	4.35 %
		8	Maintain terminal building green star rating					
Total kWhs off the national electricity grid						**3 889 550.00**	**100 %**	
Total CO_2 emissions offset (tonnes)						**4 006.24**		**100 %**

BFIA's roadmap to carbon neutrality (Fig. 7, Table 6) shows a reduction of electricity consumption from the grid, a reliance on the existing 750 kWp solar PV powerplant as a main power source, incorporation of solar thermal energy for powering absorption chillers, and excess generation of kWhs as a result of extending the existing solar PV plant to cover the airport's remaining electricity demand. There are a few surplus kWhs which can either be sold off commercially or the carbon credits can be used by another airport. The geyser sleeve technology, although feasible for BFIA [1], was excluded due to the geysers being replaced with heat pumps. Low emissivity glass (or double glazing), although feasible for BFIA [1], was reserved for new infrastructure and replacements due to existing infrastructure damage.

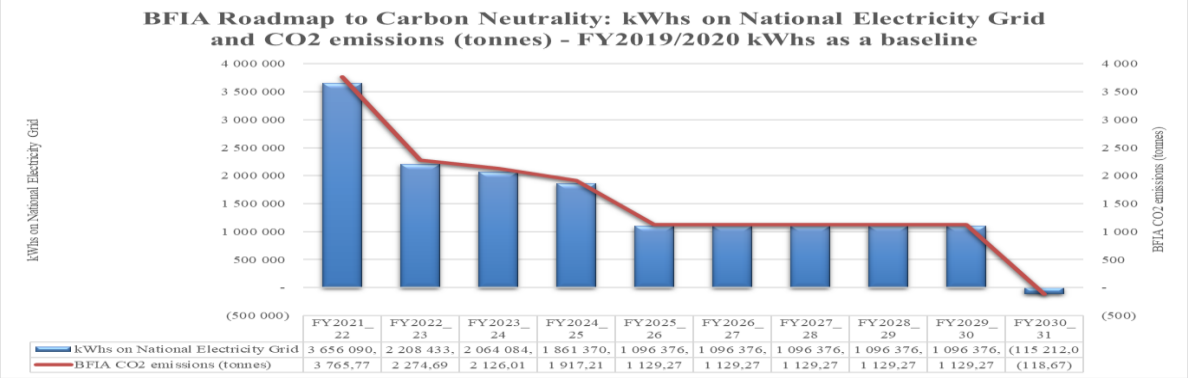

Figure 7: BFIA Roadmap to Carbon Neutrality in Electricity Consumption.

Table 6: BFIA Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	BFIA Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED	1.1	Airfield	2025	48 116.55		12.90 %	12.90 %
		1.2	High-masts	2030	160 388.51			
		1.3	Terminal and offices	2023	144 349.65			
		1.4	LED retrofits	2022	133 657.09			

	Lighting control	2.1	Lighting control system	2025	324 341.20		8.60 %	8.60 %
	Heat deflective coating	3.1	Application on terminal building roof	2024	202 713.25		5.38 %	5.38 %
Energy mix	Solar thermal absorption cooling	4.1	60 kWp solar thermal absorption plant	2025	262 800.00		6.97 %	6.97 %
	Maximising existing solar PV plant	5.1	Solar PV plant 750 kWp	2022		1 314 000.00	34.84 %	34.84 %
	Solar PV plant expansion required	6.1	600 kWp plant with energy storage for night demand from existing plant and expansion	2030		1 051 200.00	27.87 %	27.87 %
	Smart grid	7	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency culture	Existing terminal buildings green star rating	8.1	5-star green rated terminal	2025	129 736.52		3.44 %	3.44 %
		9	Maintain terminal building green star rating					
Total kWhs off the national electricity grid						**3 771 302.77**	**100 %**	
Total CO_2 emissions offset (tonnes)						**3 884.44**		**100 %**

GG airport's roadmap to carbon neutrality (Figure. 8, Table 7) shows a reduction of electricity consumption from the grid, a reliance on the existing 750 kWp solar PV powerplant as a main power source, and excess generation of kWhs as a result of extending the existing solar PV plant to cover the airport's remaining electricity demand. There are a few surplus kWhs which can either be sold off commercially or the carbon credits used for another airport. The geyser sleeve technology, although feasible for GG airport [1], was excluded due to the geysers being replaced with heat pumps.

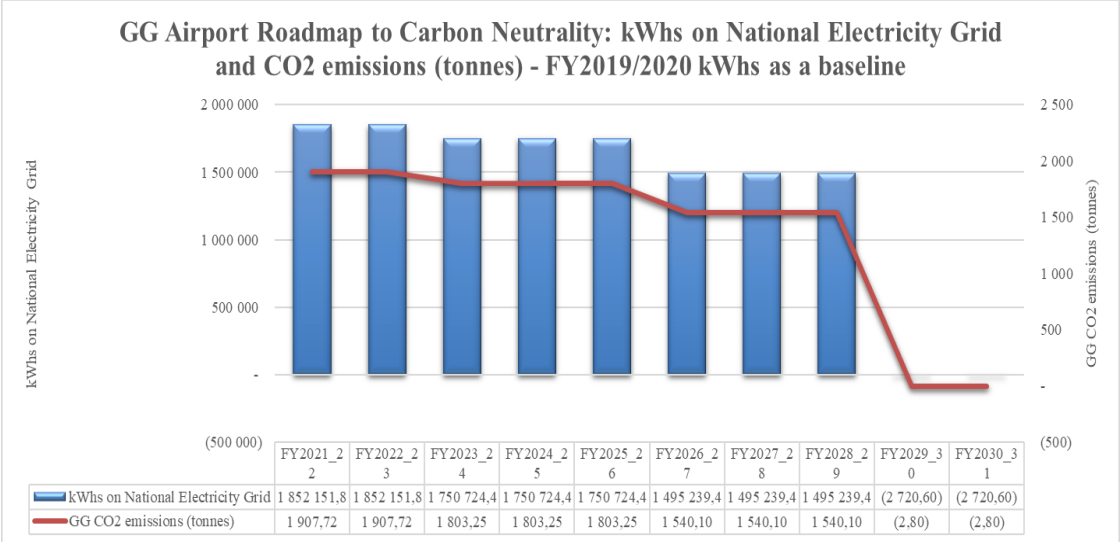

Figure 8: GG Airport Roadmap to Carbon Neutrality in Electricity Consumption.

Table 7: GG Airport Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	GG Airport Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED	1.1	Airfield	2026	101 427.36		14.98 %	14.98 %
	Lighting control	2.1	Lighting control system	2023	176 395.41			
Energy mix	Solar PV plant expansion required	3.1	900 kWp plant with energy storage for night demand from existing plant and expansion	2029		1 497 960.00	80.76 %	80.76 %
	Smart grid	4	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency culture	Existing terminal buildings green star rating	5.1	5-star green rated terminal	2026	79 089.66		4.26 %	4.26 %
		6	Maintain terminal building green star rating					
Total kWhs off the national electricity grid						**1 854 872.43**	**100 %**	
Total CO_2 emissions offset (tonnes)						**1 910.52**		**100 %**

UPIA's roadmap to carbon neutrality (Figure. 9, Table 8) shows a reduction of electricity consumption from the grid, a reliance on the existing 500 kWp solar PV powerplant as a main power source, and excess generation in kWhs as a

result of extending the existing solar PV plant to cover the airport's remaining electricity demand. There are a few surplus kWhs which can either be sold off commercially or the carbon credits used for another airport. The geyser sleeve technology, although feasible for UPIA [1], was excluded due to the geysers being replaced with heat pumps.

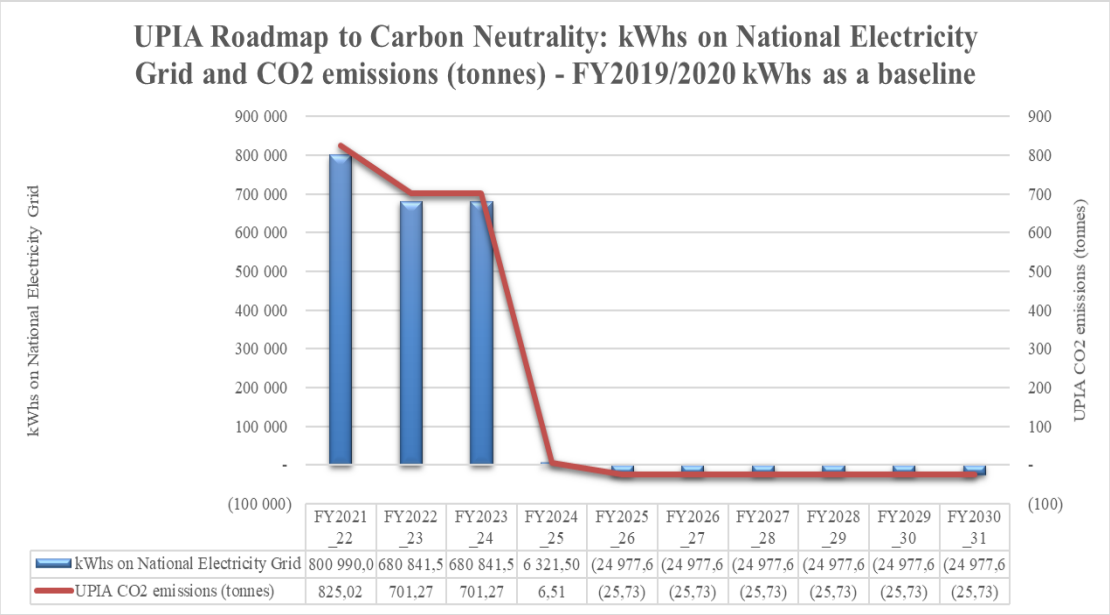

Figure 9: UPIA Roadmap to Carbon Neutrality in Electricity Consumption.

Table 8: UPIA Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	ORTIA Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED	1.1	Runway	2022	70 086.63		8.49 %	8.49 %
	Lighting control	2.1	Lighting control system	2022	50 061.88		6.06 %	6.06 %
Energy mix	Solar PV plant expansion required	3.1	200 kWp plant with energy storage for night demand from existing plant and expansion	2024		674 520.00	81.66 %	81.66 %
	Smart grid	4	Implement a smart grid to coordinate energy sources					
Embedding Energy Efficiency culture	Existing terminal buildings green star rating	5.1	5-star green rated terminal	2025	31 299.16		3.79 %	3.79 %
		6	Maintain terminal building green star rating					

Total kWhs off the national electricity grid	**825 967.66**	**100 %**	
Total CO_2 emissions offset	**850.75**		**100 %**

KIM airport's roadmap to carbon neutrality (Figure. 10, Table 9) shows a reduction of electricity consumption from the grid, a reliance on the existing 500 kWp solar PV powerplant as a main power source and an excess generation in kWhs as a result of extending the existing solar PV plant to cover the airport's remaining electricity demand. There are a few kWhs surplus which can either be sold off commercially or the carbon credits used for another airport. Low emissivity glass (or double glazing), although feasible for KIM airport [1] was reserved for new infrastructure and replacements due to existing infrastructure damage.

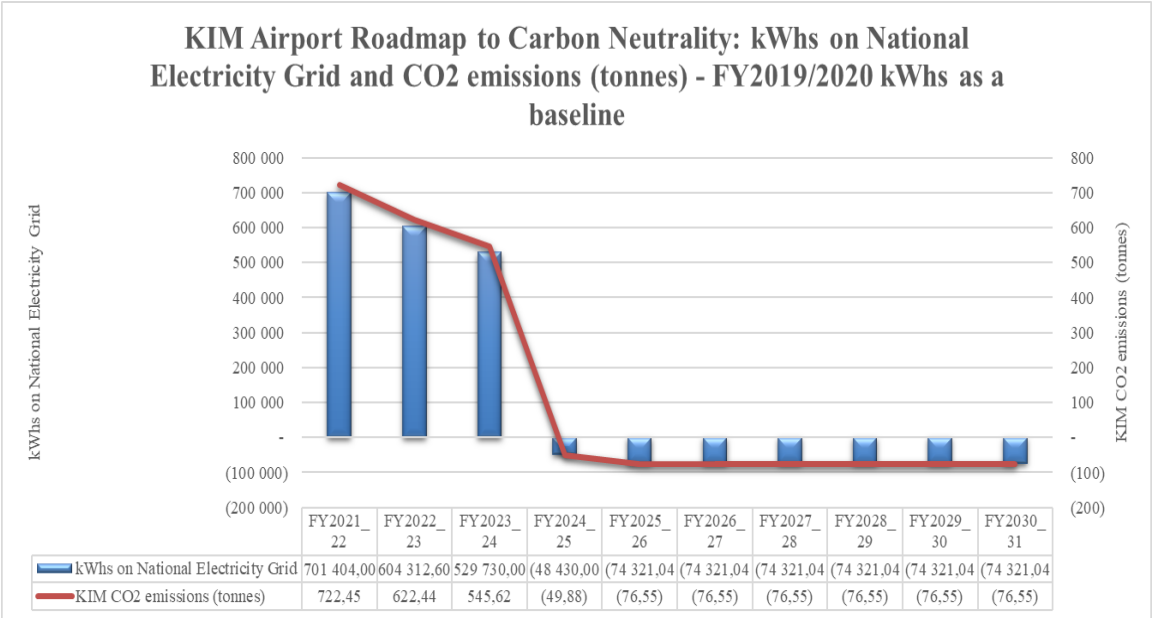

Figure 10: KIM Airport Roadmap to Carbon Neutrality in Electricity Consumption.

Table 9: KIM Airport Roadmap to Carbon Neutrality in Electricity Consumption

Objective	Project Guidance	#	ORTIA Project	Date of Beneficial Operation	kWh Savings Approximated	kWh Generation Approximated	% Impact on kWh Reduction	% Impact on CO_2 Emissions Reduction
Reduction in kWh consumption	Lighting change to LED	1.1	Airfield	2022	97 091.40		12.52 %	12.52 %
	Lighting control	2.1	Lighting control system	2023	64 727.60		8.34 %	8.34 %
	Geyser sleeve technology	3.1	Geyser sleeve retrofit	2023	9 855.00		1.27 %	1.27 %
Energy mix	Solar PV plant expansion required	4.1	150 kWp plant with energy storage for night demand	2024		578 160.00	74.53 %	74.53 %

			from existing plant and expansion					
	Smart grid	5	Implement a smart grid to coordinate energy sources					
Embedding energy efficiency culture	Existing terminal buildings green star rating	6.1	5-star green rated terminal	2025	25 891.04		3.34 %	3.34 %
		7	Maintain terminal building green star rating					
Total kWhs off the national electricity grid						**775 725.04**	**100 %**	
Total CO_2 emissions offset (tonnes)						**799.00**		**100 %**

Each airport's roadmap to carbon neutrality is currently live and implementation will be adjusted according to circumstances and the changing energy demands of the airports. Geyser sleeves were investigated for all the airports and proved feasible; however, their implementation will not be needed at airports where heat pumps have been installed. It was decided that retrofitting glass facades with low emissivity or double glazing will not be the best approach and should rather be used in new installations as well as in repairs if appropriate. Implementation will be adjusted according to circumstances and the changing energy demands.

The roadmaps to carbon neutrality in electricity consumption for the airports aim to offset the quantity of carbon emissions as of the financial year ending 31 March 2020. Future electrical loads will be subject to the standards and guidelines for energy efficiency [10] and new infrastructure projects will be required to attain a green star certification. This will ensure that new loads are efficient and the roadmaps to carbon neutrality efforts are maximised. The intention is to increase the capacity of existing power plants to either supply new loads and/or offset carbon emissions.

3. CONCLUSIONS

This paper presented the confirmed low carbon, economically feasible energy mix and the green star rating targets for the nine airports in South Africa owned and operated by ACSA, and the associated roadmaps to carbon neutrality. The main low carbon energy source for ORTIA, CTIA and KSIA is natural gas trigeneration plants that will provide electrical kWhs and heat for water heating purposes and power absorption chillers for air conditioning. Wind energy and geothermal heat sinks are also in the energy mix for CTIA. To offset the carbon emissions from natural gas engines, solar PV plants are used. Excess generation from the carbon offsetting solar PV plants can be commercialised or can be targeted as an offsite corporate social investment project, claiming carbon credits. Solar PV energy with energy storage is the main energy source for PEIA, EL airport, BFIA, GG airport, UPIA and KIM airport. Solar thermal energy powering absorption chillers at PEIA and BFIA further reduce kWhs from the electricity grid. Wind energy is also in the low carbon-energy mix for PEIA. The roadmaps to carbon neutrality offset the carbon emissions from the airports' electricity consumption from the grid, and the green star ratings targeted for existing terminal buildings as well as for new infrastructure ensures that investment into carbon neutrality is sustained and optimised.

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